Space Weather Technical Forecast

Issued on Tuesday 31 December 2024 at 13:15 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

---

Space Weather Forecast Headline: R1/R2 Radio Blackouts expected with a slight chance of R3 blackouts. A CME arrival is expected on 31 Dec, with G1-G2 Minor/Moderate storm likely, with a slight chance of G3 Strong storm.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: High levels with six M-class flares in the last 24 hours, the peak being an M5 flare from AR3936 at 30/1654 UTC. AR3936 has produced the majority of the recent M-class flares, with AR3939 in the southeast also contributing.

There are currently ten sunspot regions on the visible disc. AR3936 is the largest and most active region in the northwest quadrant, but has been relatively stable and showing some signs of decay in its trailing spots. AR3939 shows some complexity with positive polarity spots surrounding negative spots in the centre, perhaps showing some indication of its centre spot getting closer to the smaller leading spots. AR3938 appears to be stable, with some of the intermediate spots starting to slowly fade. AR3932 continues to fade with many of the spots weakening markedly. AR3941 is stable, with the region slowly spreading horizontally. AR3942 has rapidly increased in complexity in the last 24 hours, going from a simple Bxo classification to a Dso and is one to be watched. Newly numbered AR3943 in the southeast remains difficult to analyse due to its oblique viewing angle, but should become clearer as it rotates further onto the disc.

A filament eruption and dimming event was observed on GONG H-alpha imagery in the vicinity of AR3939 at 29/0436 UTC, which produced a partial halo CME seen in LASCO and STEREO-A imagery. This event has been analysed and the results show an Earth-directed CME, which is expected to arrive at Earth on Day 1 (31 Dec).

Another partial halo emerged in LASCO imagery after 29/1800UTC, likely associated with AR3939 and likely having an Earth-directed element arriving on Day 2 (01 Jan). Although it appears to be rather faint compared to the previous event, with less material expected.

Solar Wind / Geomagnetic Activity: Solar winds, as observed at L1 by ACE remained at background levels throughout, between 330-350km/s rising to 380km/s from 31/1130 UTC. Density was mostly below average, with a very brief period of average around 31/0300-0400 UTC. The Interplanetary Magnetic Field (IMF) was mainly weak with brief periods of moderate. The north-south component remained weak and variable, ranging from -8nT to +8nT. Phi angle was mostly positive (away from the Sun). Quiet geomagnetic activity throughout (Kp 0-2).

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 370 900 0100 Email: enquiries@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV) at GOES18 remained at background throughout, well below the S1/Minor Radiation Storm threshold.

High energy electron flux (greater than 2MeV) at GOES16 was at Background, diurnally peaking at Moderate levels, peaking at 30/2055 UTC at 164pfu. The associated 24-hour fluence was below the Active (1e8 integrated flux) threshold on a slightly declining trend. The 31/0001UTC observation was 3.21e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Moderate to High solar activity is forecast with frequent Moderate flares expected on Days 1 and 2 (31 Dec - 01 Jan) and a slight chance of isolated X-class flares, especially from AR3936.

Solar Wind / Geomagnetic Activity: No coronal hole fast winds currently feature in the forecast. A partial halo CME observed in SOHO LASCO C2/C3 looks to be associated with an M2.0 flare and a filament eruption near the vicinity of AR3939 in the southeast quadrant at around 29/0440UTC a dimming was observed in GOES SUVI imagery. This event has been analysed, with an Earth-directed CME expected to arrive on Day 1 (31 Dec). A second, slower partial halo CME was observed from AR3939 later on 29 Dec, with the potential to reach Earth on Day 2 (01 Jan), however little material is expected with this second CME.

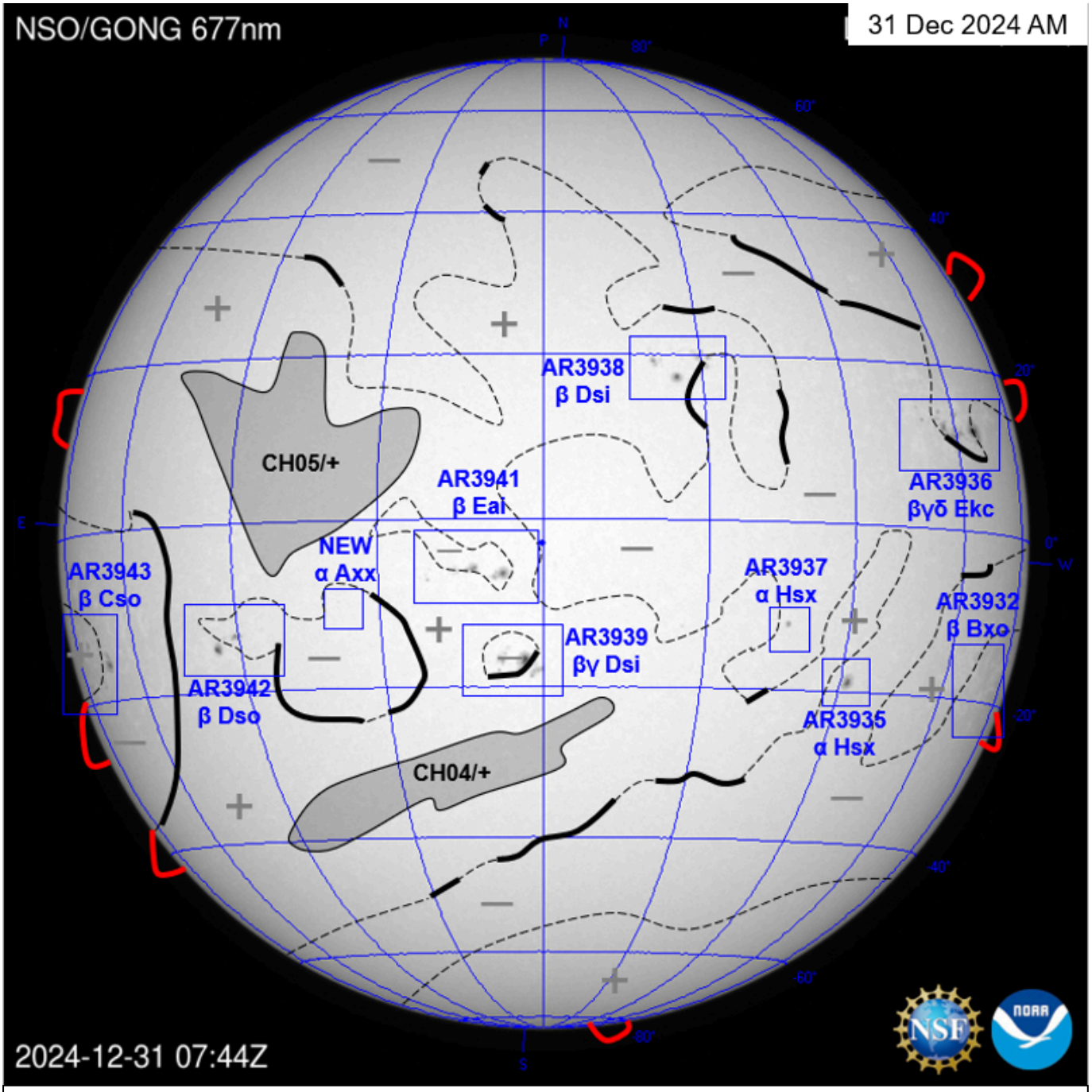
Geomagnetic activity is expected to increase from Quiet due to the aforementioned Earth-directed CMEs arriving on Days 1-2 (31 Dec - 01 Jan) and are likely to enhance geomagnetic activity, reaching G1-G2 Minor/Moderate storm, with a slight chance of G3/Strong storm. Any CME effects gradually waning on Day 3 (02 Jan), back towards Quiet to Unsettled conditions.

Energetic Particles / Solar Radiation: There is a slight chance of S1/Minor Radiation Storm enhancements during the period, should any significant flares occur from the larger regions on the disc as they rotate into the western hemisphere. Electron flux levels remain Background to Moderate but are expected to gradually ease into the period with enhanced geomagnetic activity. Electron fluence will most likely remain below the Active threshold.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 370 900 0100 Email: enquiries@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

Figure 1: Solar Synoptic Map valid 31/0744 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 370 900 0100 Email: enquiries@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

Geomagnetic Storms

A filament lift-off (following an M2 flare) from the southeast quadrant, close to AR3939 around 29/0436 UTC appears to have produced a fast partial halo CME, which has been analysed as Earth-directed, with an expected arrival on Day 1 (31 Dec). A second partial halo CME was observed leaving the Sun later on the 29 Dec in association with a M3.3 flare from AR3939 in the southeast, this may bring some enhancement on Day 2 (01 Jan) although there does not appear to be much material associated with the shock. Following on from the X1.5 flare from AR3936 on 30/0414 UTC, some slow ejecta can be seen leaving the Sun at this time, after some analysis, this now looks to comfortably pass to the north and head of Earths orbit.

Solar winds are otherwise are averaging around 350-380km/s and are expected to increase due to the arrival of the aforementioned CME on Day 1 (31 Dec), where solar winds could reach elevated to strong levels, between 500-700km/s.

Any fast wind enhancement from CH05+ is likely to be minimal given the proximity to the winter solstice and not until after the current forecast period.

The arrival of the anticipated partial halo CME, which left the Sun on the 29 Dec, shortly followed by the second partial halo CME is likely to enhance geomagnetic activity to G1-G2/Minor-Moderate storm levels, with a slight chance of reaching a G3/Strong storm interval on Days 1-2 (31 Dec - 01 Jan). Any CME effects gradually waning into Day 3 (02 Jan), back towards Quiet to Unsettled conditions, with isolated Active intervals.

Geomagnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	60	60	20	5
Strong	G3	No	20	20	5	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

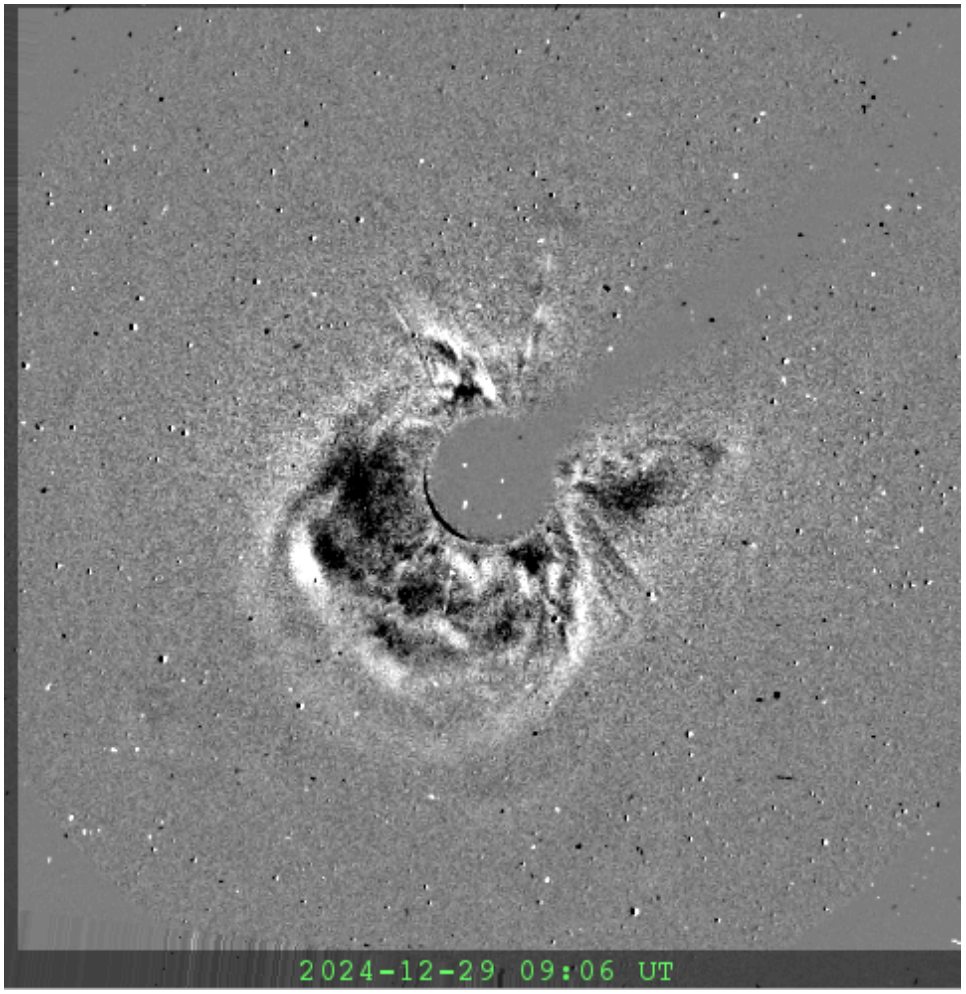
Issued by Met Office Space Weather Advisor, Tel: +44 (0) 370 900 0100 Email: enquiries@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R⊙ (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed (km/s)	Estimated Arrival Time (UTC)	Comments
2024-12-29 (0955UTC)	Partial	Near AR3939	Southeast	1015km/s	2024-12-31 (1500UTC)	M2 flare and associated filament eruption near AR3939 produced a partial halo CME.
2024-12-29 (2310 UTC)	Partial	AR3939	Southeast	697 km/s	2025-01-01 (0900UTC)	M3.3 flare from AR3939

Figure 2: SOHO LASCO C3 difference imagery, showing the partial halo CME, which has been analysed as Earth-directed, arriving on Dec 31.



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 370 900 0100 Email: enquiries@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

Figure 3: MOSWOC Enlil output.

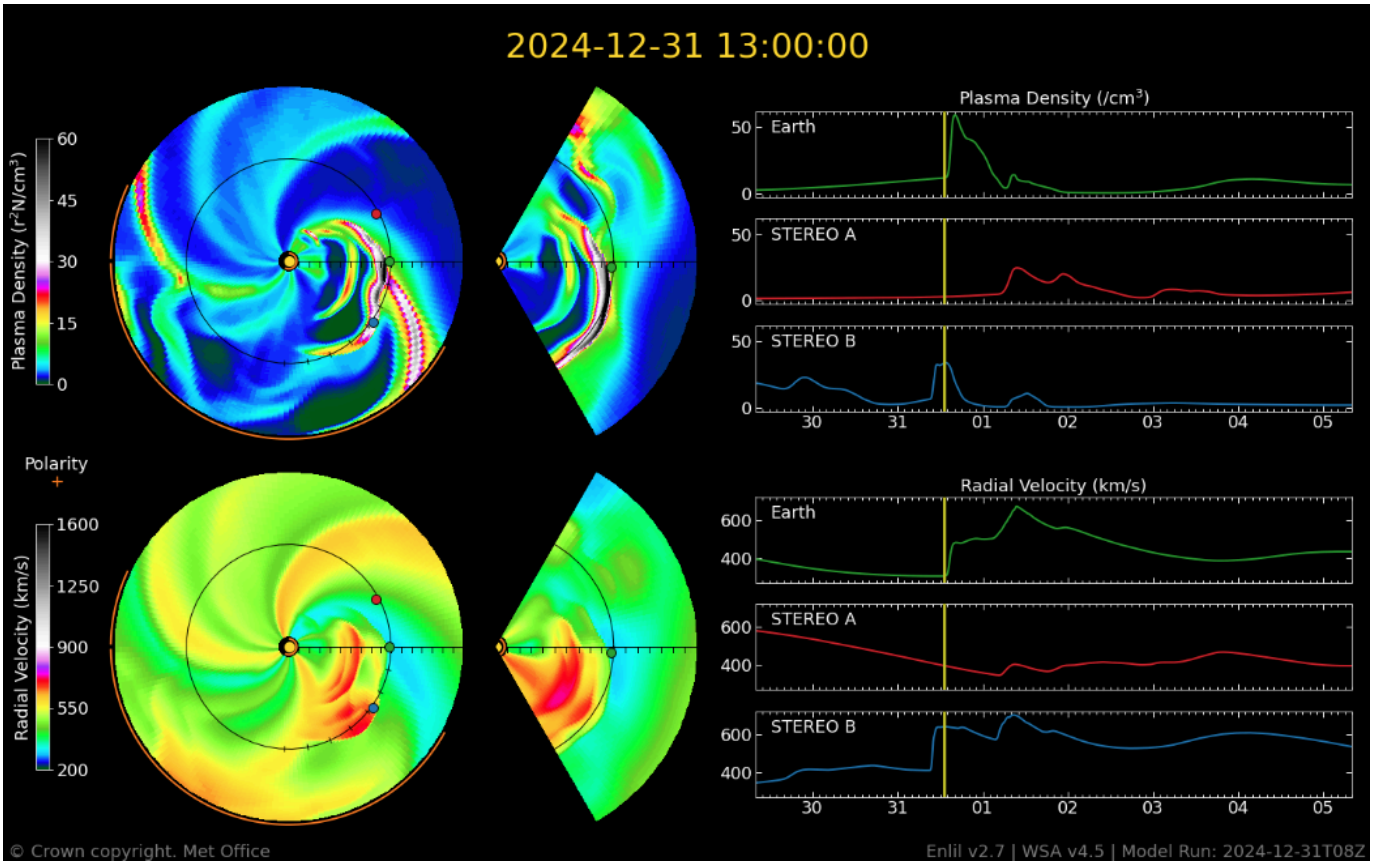
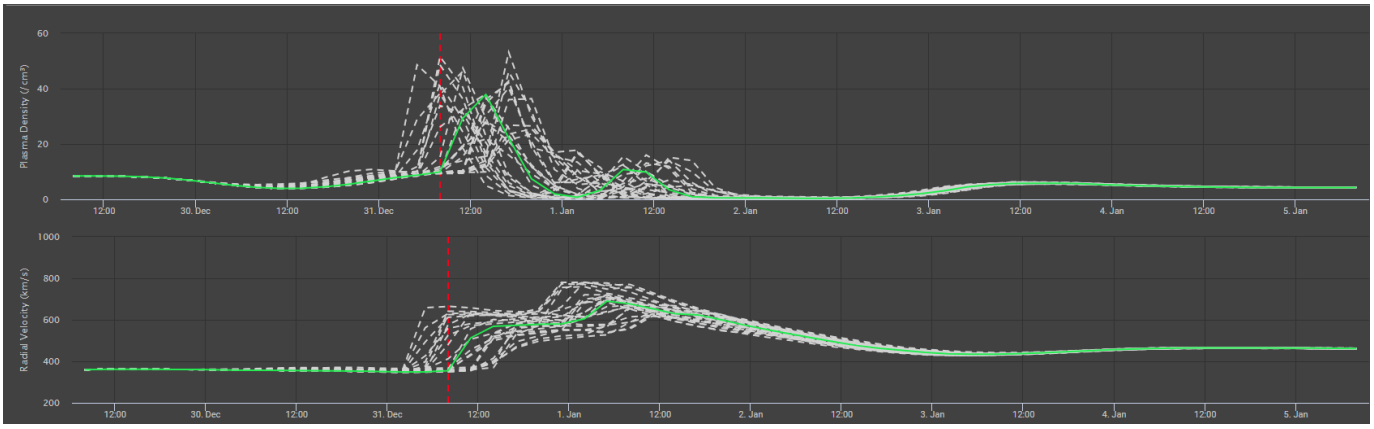


Figure 4: MOSWOC Ensemble output showing the arrival of the CME during Day 1 (31 Dec) and the second CME during Day 2 (01 Jan).



© Crown Copyright 2024. All Rights Reserved.

Radio Blackouts - X-Ray Flares

Solar activity is currently at High levels with six M-class flares in the last 24 hours. There are currently ten sunspot regions on the visible disc. AR3936 is the largest and most active region, classified as a beta-gamma-delta, and has produced the majority of the M-class flares over the last 24 hours, including the peak M5 at 30/1654 UTC. However, it has been relatively stable and in recent imagery has shown some signs of decay in its trailing spots. AR3938 appears to be stable, with some of the intermediate spots starting to slowly fade. AR3932 continues to fade with many of the spots weakening markedly. AR3941 is stable, with the region slowly spreading horizontally. AR3942 has rapidly increased in complexity in the last 24 hours, going from a simple Bxo classification to a Dso and is one to be watched. Newly numbered AR3943 in the southeast remains difficult to analyse due to its oblique viewing angle, but should become clearer as it rotates further onto the disc. The remaining regions are small and magnetically simple.

AR3939 shows some complexity with positive polarity spots surrounding negative spots in the centre, perhaps showing some indication of its centre spot merging with its smaller leading spots. Recent activity near the vicinity of AR3939 in the southeast associated with an M2.0 flare at 29/0436 UTC and a subsequent filament eruption, produced a partial halo CME. This event has been analysed as Earth-directed, with the CME expected to arrived at Earth during the second half of 31 Dec. A second partial halo CME was observed leaving the Sun later on the 29 Dec in association with a M3.3 flare from AR3939 in the southeast, this may bring some enhancement during the first half of 01 Jan.

Recurrence suggests that no significant sunspot regions are expected to rotate around the eastern limb in the short term and this is backed up by far-side sounding output which is not showing any significant regions. Any looping in SUVI imagery close to the eastern limb is most likely associated with AR3943. This combined with AR3932 and AR3936 rotating around the western limb in the coming days will see a gradual reduction in the risk of M-class flares from Day 3 (02 Jan).

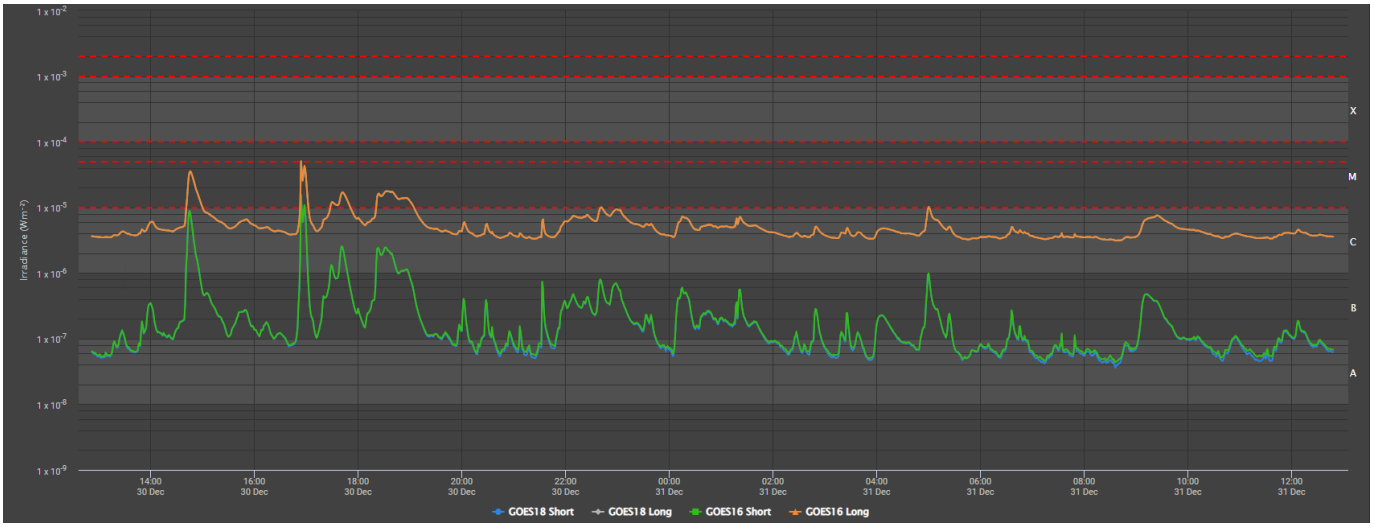
Moderate to High solar activity is forecast with frequent Moderate flares expected on Days 1 and 2 (31 Dec - 01 Jan) and a slight chance of isolated X-class flares, especially from AR3936.

X-Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 (M Class)	Yes	80	80	60	60
Very Active	R3-R5 (X Class)	No	20	20	10	10

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 370 900 0100 Email: enquiries@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

Figure 5: GOES 16 & 18 X-ray trace.



© Crown Copyright 2024. All Rights Reserved.

Solar Radiation Storms (High Energy Protons)

High energy proton counts remain at Background values, with neither the X1.5 flare from AR3936 or the filament eruption from the southeast quadrant resulting in a noticeable increase in proton counts. There remains a slight chance of S1/Minor Solar Radiation storms should any significant flares occur from the larger regions on the disc as they rotate into more favourable locations for a connection to Earth.

Radiation Storms Probability (Exceedance)	Level ($cm^{-2}sr^{-1}s^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	20	20	20	20
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and/or 50 MeV ≥ 10pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 370 900 0100 Email: enquiries@metoffice.gov.uk

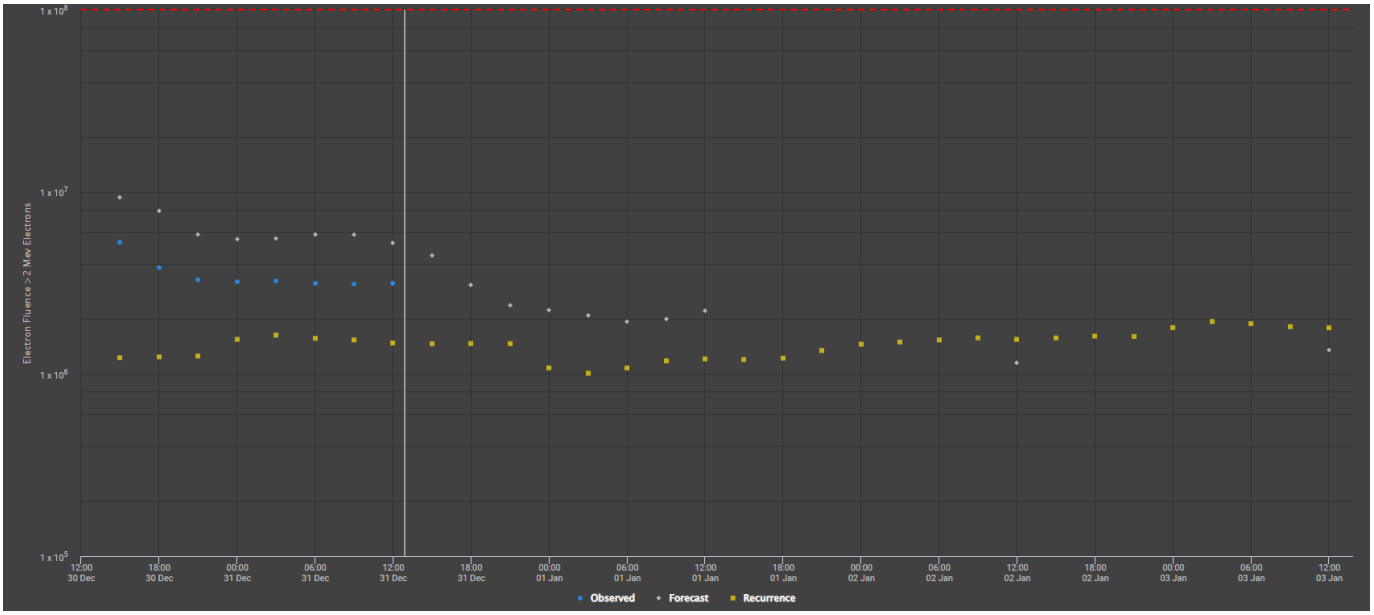
© Crown Copyright 2024. All Rights Reserved.

High Energy Electrons (≥ 2MeV)

High energy electron flux has remained at Background, with diurnal peaks up to Moderate levels in the last 24 hours. Electrons are likely to appear suppressed with the arrival of a CME on Day 1 (31 Dec) as the Van Allen belt becomes compressed away from the location of GEO. This may expand again after the current forecast period, seeing a rise in the electron levels. Electron fluence will most likely remain below the Active threshold throughout, as shown in MOSWOC REFM output, which is considered good guidance.

GEO Electron Environment	Level ($cm^{-2}sr^{-1}$ day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ 1×10^{8}	No	5	5	5	5
Very Active	≥ 2 MeV ≥ 1×10^{9}	No	1	1	1	1

Figure 6: MOSWOC REFM output.



© Crown Copyright 2024. All Rights Reserved.